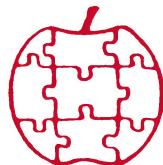


Apple Assembly Line



Volume 7 -- Issue 10

July, 1987

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New IIgs Books from Apple

We now have copies of three new books from Apple, via Addison-Wesley Publishing. The "ProDOS-8 Technical Reference Manual" replaces the old "ProDOS TRM". It is still the same price, but it is slightly updated and is now a hardcover book rather than spiral-bound paperback. In fact, all of the new Apple books are apparently in hard-cover. They are very well made books.

The "Apple IIgs ProDOS-16 Reference" is a brand new book, and one you need if you are going to be programming for the ProDOS-16 environment. Even more important to IIgs programmers is the new "Apple IIgs Firmware Reference". See inside for more information about both of these and other new titles in the series.

Is the "Sider" Still Available?

We have had a lot of callers ask this question, so we finally called Xebec to find out. The answer is "Yes", but not through direct phone or mail orders from First Class Peripherals. You now have to order them through dealers, of which there apparently quite a few. You can get a list of dealers near you by calling (800) 982-3232. Meanwhile, we are trying to get set up as dealers ourselves. If you are in the market for a good 20- or 40-megabyte hard disk, give us a call.

Clearing Some Mist from Super-HiRes.....Bob Sander-Cederlof

The Apple IIgs has lot of new features, and one of the most obvious is the new Super HiRes graphics mode. It allows display of 200 lines of either 320 dots or 640 dots each. In the 320x200 mode each dot is represented by four bits, and in the 640x200 mode each dot is represented by two bits. A scan control byte for each of the 200 lines determines whether that line is 320 or 640 pixels, and which of 16 color palettes to use for that line.

By experimentation, I found the description of Super HiRes in the Apple documentation to be incorrect in some areas. Other sources of information I found were incomplete. Hopefully the following will fill in some of the gaps, and correct some of the errors. If you catch me making some new ones, please let me know!

The information which controls the super hires display consists of three elements: the picture, the scan control bytes, and the color palettes. There are 200 scan control bytes (SCB's), one for each line of graphics. The low-order four bits of each SCB are the palette number to use for that scan line. Bit 7 indicates whether the scan line is in 320- or 640-mode. Bit 6 controls the generation of an IRQ interrupt at the beginning of the scan line. Bit 5 selects the fill mode. Bit 4 is not used (yet). (The SCB description in the documentation I have from Apple erroneously has the 320/640 bit in bit 0, and the palette index in bits 7-4.)

There are 16 color palettes, each having 16 two-byte color entries. The color used for each individual pixel is controlled by the palette number from the scan control byte, the pixel value, and (in 640-mode) the pixel position. The bits in each palette control the brightness of each of the three primary video colors, red, green, and blue. Bits 15-12 of the palette entry are not used. Apple says to keep these zeroed, in case they think of some way to use them in the future. Bits 11-8 are the intensity value for red; bits 7-4, green; and bits 3-0, blue.

All the soft switches which control Super HiRes are at \$C029. Bit 7 turns Super HiRes on and off. Bit 6 controls the order that software sees the bytes in the display area. Bit 0 of this byte needs to remain set to 1 or the IIgs crashes. To turn on Super HiRes, store \$C1 or \$81 at \$C029; to turn it off, store \$41 or \$01. I prefer \$C1 and \$41, because this leaves the graphics area in what Apple calls "linear" address order.

The bytes from \$2000 through \$9FFF in bank \$E1 are used for Super HiRes. (If shadowing is on, the same addresses are also available in bank \$01.) When bit 6 of \$C029 is set to a 1, these bytes are in a nice logical order for software access. Locations \$2000-\$9CFF are the picture area of 32000 bytes. Each scan line occupies 160 contiguous bytes in this range. The 200 scan control bytes run from \$9D00 through \$9DC7. The 56 bytes at \$9DC8-\$9DFF are not used for anything at this time. Apple says they should be cleared to zero, but they do not do

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so in their own software. The color palettes are kept in \$9E00-9FFF, 32-bytes for each palette.

When bit 6 of \$C029 is cleared to zero, the Super HiRes data is located differently. It is still in bank \$E1 from \$2000 through \$9FFF, but in a different order. All the even bytes of the picture are stored in \$2000-5E7F; the even scan control bytes, in \$5E80-5EFF; and the even bytes of the palettes, in \$5F00-5FFF. The odd bytes are found in the corresponding positions in \$6000-9FFF. I don't know why Apple gave us the ability to see the bytes in this order, but apparently this is the order the video hardware sees. Software will almost always set bit 6 and see them in the "linear" order.

In 320-pixel mode, the pixel number is a value from 0 to 319 decimal, or 0 to \$013F hex. If we divide the pixel number by two, the quotient gives the byte position on the line and the remainder gives the pixel position in the byte. Pixel 0 in a byte is in bits 7-4, and pixel 1 is in bits 3-0. The 4-bit value of a pixel is used as an index to pick one of 16 colors out of the palette designated for the line.

In 640-pixel mode, the pixel number is a value from 0 to 639 decimal, or 0 to \$027F hex. If we divide the pixel number by four, the quotient gives the byte position on the line and the remainder gives the pixel position in the byte. Pixel 0 in a byte is in bits 7 and 6, pixel 1 is in bits 5 and 4, and so on. Let's look at a 16-bit pixel number, and break it down this way: 000000ab cdefghij. Then the byte number in the scan line is "abcdefg", and the pixel number is "ij". The index used to pick which of 16 colors in the current palette to use for the pixel is computed by adding the two-bit pixel value to four times the pixel position.

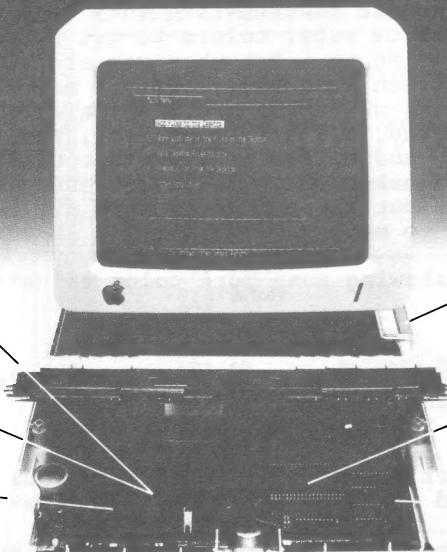
Stating it again, in a different way, the address of the color bytes for an individual pixel can be easily calculated, using one of the following formulas:

$$\begin{array}{ll} \text{320-mode} & \$9E00 + PPPP*32 + pppp*2 \\ \text{640-mode} & \$9E00 + PPPP*32 + xxpp*2 \end{array}$$

where \$9E00 is the base address for the 16 palettes; PPPP is the palette # from the scan control byte; pppp is the 4-bit pixel value in 320-mode; xx is the low-order two bits of the pixel number in 640-mode, and pp is the two-bit pixel value in 640-mode.

Probably most users of the Super HiRes graphics will use the 320-pixel mode, because it is so easy to get 16 brilliant colors for every pixel. Most uses of the 640-pixel mode will probably be displaying text in one of three colors with the background set to a fourth color. By storing the same four colors in each of the four groups of a palette, you can easily achieve the four-color effect. However, you are not LIMITED to four colors. By being VERY smart and careful, you could use 16 different colors in the 640-pixel mode.

ANother interesting puzzle, at least to me, is how to determine



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what color numbers to use to get a particular color on the screen. When I was in kindergarten they told me about mixing red, blue, and yellow water colors to get purple, green, orange, brown, and so on. But when you are mixing light, you start with red, green, and blue. If you mix all three in equal amounts you get the shades of gray. A palette entry of \$0444 would be a dark gray, \$0888 a light gray, and \$0FFF we could call white. Red and blue mixed together still make purple, but red and green make yellow! You artists and photographers and video experts out there already know all this, but it is still mysterious to me.

Here is a chart showing some more color values:

R G B	Color	R G B	Color
8 4 1	Brown	7 2 C	Dark Purple
F 7 0	Orange	F A 9	Pink
0 0 F	Dark Blue	0 E 0	Light Green
F F 0	Yellow	D A F	Light Purple
0 8 0	Dark Green	4 D F	Light Blue
D 0 0	Red	7 8 F	Grayish-Blue

The following program will turn on the super hi-res graphics and draw a picture showing the above colors in 16 vertical stripes. The bottom 16 scan lines will show a second palette of colors, which I have set to shades of gray.

Line 1020 tells the S-C Macro Assembler to allow assembly of 65816 opcodes and addressing modes. Lines 1070-1080 turn on the super hi-res graphics, and lines 1180-1190 turn it back off. Lines 1100-1120 call subroutines to set up the scan control bytes, load in two palettes of colors, and draw the "picture". Lines 1140-1160 wait until any key is pressed. So, after assembling with the S-C Macro Assembler, typing "MGO T" will cause the picture to appear. Then pressing any key will bring back the text screen.

The scan control bytes for the first 184 lines will all equal \$00, because I want 320-pixel mode and I am using palette 0. The last 16 lines I use \$01 for the SCB values, to draw them using palette 1.

Lines 1780-1810 save the current 65816 mode and enter the Native Mode. Lines 1960-1980 restore the original mode. Lines 1830-1940 generate 32000 bytes of picture data. Each scan line has 160 bytes of pixels. My loops here store ten zeroes, ten \$11-bytes, ten \$22-bytes, and so on through ten \$FF-bytes in each scan line. I used 16-bit mode for the index registers, and 8-bit mode for the A-register.

After you have run the program once and seen the color stripes, you might like to go back and change line 1860 to LDY #\$5. The assemble and run it again. You will get two sets of color stripes of half the width of the previous picture. Then you can try changing it to other even multiples of 5, like 20 and 40.

```

1010      .OP 8
1020 *SAVE S.TEST.SHRC
1030 *
1040 *   TEST SUPER HI-RES COLOR
1050 *
1060 T
000800- A9 C1 1070      LDA #$C1      Turn on super hi-res screen
000802- 8D 29 CO 1080      STA $C029
1090 *---Build Picture-----
000805- 20 1C 08 1100      JSR SCAN.CONTROL.BYTES
000808- 20 2E 08 1110      JSR PALETTE
00080B- 20 7B 08 1120      JSR PICTURE
1130 *---Wait till keypress-----
00080E- AD 00 CO 1140      LDA $C000
000811- 10 FB 1150      BPL .1
000813- 8D 10 CO 1160      STA $C010
1170 *---Turn off graphics-----
000816- A9 41 1180      LDA #$41
000818- 8D 29 CO 1190      STA $C029
00081B- 60 1200      RTS
1210 *
1220 SCAN.CONTROL.BYTES
00081C- A9 00 1230      LDA #0      Palette 0, 320-pixel mode
00081E- A2 00 1240      LDX #0      ...for lines 0...183
000820- 9F 00 9D E1 1250      .1      STA $E19D00,X
000824- E0 B8 1260      CPX #184
000826- 90 02 1270      BCC .2      Use palette 1 for lines
000828- A9 01 1280      LDA #1      184...199
00082A- E8 1290      INX
00082B- D0 F3 1300      BNE .1
00082D- 60 1310      RTS
1320 *
1330 PALETTE
00082E- A2 3F 1340      LDX #PALSIZE-1      Copy the two palettes
000830- BD 3B 08 1350      .1      LDA PALDATA,X      into palette area
000833- 9F 00 9E E1 1360      STA $E19E00,X
000837- CA 1370      DEX
000838- 10 F6 1380      BPL .1
00083A- 60 1390      RTS
1400 *
1410 PALDATA
00083B- 00 00 1420      .HS 00.00      BLACK
00083D- 77 07 1430      .HS 77.07      DARK GREY
00083F- 41 08 1440      .HS 41.08      BROWN
000841- 2C 07 1450      .HS 2C.07      DARK PURPLE
000843- 0F 00 1460      .HS 0F.00      DARK BLUE
000845- 80 00 1470      .HS 80.00      DARK GREEN
000847- 70 0F 1480      .HS 70.0F      ORANGE
000849- 00 OD 1490      .HS 00.OD      RED
00084B- A9 OF 1500      .HS A9.OF      PINK
00084D- F0 OF 1510      .HS F0.OF      YELLOW
00084F- E0 00 1520      .HS E0.00      LIGHT GREEN
000851- DF 04 1530      .HS DF.04      LIGHT BLUE
000853- AF OD 1540      .HS AF.OD      LIGHT PURPLE
000855- 8F 07 1550      .HS 8F.07      GREY-BLUE
000857- CC OC 1560      .HS CC.OC      LIGHT GREY
000859- FF OF 1570      .HS FF.OF      WHITE
1580 *
00085B- 00 00 1590      .HS 00.00      BLACK
00085D- 11 01 1600      .HS 11.01
00085F- 22 02 1610      .HS 22.02      VARIOUS
000861- 33 03 1620      .HS 33.03      SHADES
000863- 44 04 1630      .HS 44.04      OF
000865- 55 05 1640      .HS 55.05      GRAY
000867- 66 06 1650      .HS 66.06
000869- 77 07 1660      .HS 77.07
00086B- 88 08 1670      .HS 88.08
00086D- 99 09 1680      .HS 99.09
00086F- AA 0A 1690      .HS AA.0A
000871- BB OB 1700      .HS BB.0B
000873- CC OC 1710      .HS CC.OC
000875- DD OD 1720      .HS DD.OD
000877- EE OE 1730      .HS EE.OE
000879- FF OF 1740      .HS FF.OF      WHITE
40- 1750 PALSIZE .EQ #-PALDATA

```



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```

1760 *-----  

1770 PICTURE  

00087B- 08 1780 PHP ENTER NATIVE MODE  

00087C- 18 1790 CLC  

00087D- FB 1800 XCE  

00087E- 08 1810 PHP  

1820 *-----  

00087F- C2 11 1830 REP #$11 CLC, x=0  

000881- A2 00 00 1840 LDX #0 For X = 0 to 31999  

000884- A9 00 .1 1850 LDA #0 For A = $00 to $FF step $11  

000886- A0 0A 00 1860 :2 LDY #10 For Y = 10 to 1 step -1  

000889- 9F 00 20 E1 1870 .3 STA $E12000,X  

00088D- E8 1880 INX Next x  

00088E- 88 1890 DEY Next Y  

00088F- D0 F8 1900 BNE .3  

000891- 69 11 1910 ADC #$11 Next A  

000893- 90 F1 1920 BCC .2  

000895- E0 00 7D 1930 CPX #$32000  

000898- 90 EA 1940 BCC .1 More to this screen  

1950 *-----  

00089A- 28 1960 PLP RETURN TO EMULATION MODE  

00089B- FB 1970 XCE  

00089C- 28 1980 PLP  

00089D- 60 1990 RTS  

2000 *

```

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A+ September Puzzle Solved.....Bob Sander-Cederlof

The September issue of A+ Magazine gives the winning solutions to the puzzle we solved in our May issue of AAL. Mine didn't win, perhaps because I did not send it in. It also gives a new interesting puzzle: find an 8-digit number which is the square of a multiple of seven of the form "ababbbcc".

I wrote three different Applesoft programs to solve this puzzle, testing different algorithms. Then I converted one of them to assembly language. The assembly version finds the only answer in the astonishing time of less than 600 milliseconds! It also illustrates a few interesting programming techniques.

In trying to figure out how to efficiently solve this problem, I first noticed that only three different digit values occur in the answer. The smallest possible number of the form ababbbcc is 10100022, and the largest possible answer is 98988877.

Taking the square root of these two values, I find the smallest multiple of 7 to test is 3185 (7 times 455), and the largest is 9947 (7 times 1421). I can run through all the multiples of 7 between these two values and test the digits in the square to see if they follow the pattern. Here is one way to do that:

```
100 FOR X = 3185 TO 9947 STEP 7
110 N = X * X
120 A = INT (N / 100000)
130 A1 = INT (A / 100):A3 = A - A1 * 100
140 A2 = INT (A3 / 10): IF A1 = A2 THEN 300
150 A3 = A3 - A2 * 10: IF A1 < > A3 THEN 300
160 B = ((A2 * 10 + A2) * 10 + A2) * 100
170 A = N - A * 100000
180 IF A < B OR A > B + 99 THEN 300
290 PRINT N" = ( 7 * "X" ) ^ 2"
300 NEXT
```

Since there are 967 multiples of seven in that range, the program above has to test 967 numbers to find whatever solutions there may be. It takes about 51 seconds to find the one and only solution. My next approach only has to test 270 different numbers, so it runs considerably faster (less than 13 seconds).

This time I decided to build all possible numbers of the form ababbbcc, and then test them to see if they were perfect squares of multiples of seven. Here is the program:

```
100 FOR A = 10100000 TO 90900000 STEP 10100000
110 FOR B = 0 TO 9099900 STEP 1011100
120 FOR C = 1 TO 99 STEP 49
130 N = A + B + C
140 NN = INT (N / 49) * 49
150 LO = NN - INT (NN / 100) * 100
160 IF LO > C THEN 300
170 L1 = INT (LO / 10): IF L1 < > (LO - L1 * 10) THEN 300
180 S = INT (SQR (NN)): IF S * S < > NN THEN 300
290 PRINT NN" = ( 7 * "S / 7" ) ^ 2"
300 NEXT : NEXT : NEXT
```

Lines 100-130 will generate all numbers of the form ababbb00+C, where C is 1, 50, or 99. Line 140 will generate the number N smaller than or equal to ababbb00+C which is a multiple of 49 (squares of a multiple of 7 will be multiples of 49). Lines 150-170 make sure the last two digits are the same, giving the number the form ababbbcc. Finally, line 180 checks to see if the test number is a perfect square.

Neither of these two algorithms would be particularly easy to convert to assembly language, because of the multiplication and division steps needed. Therefore I developed yet another method, a modification of the first program above. I realized that stepping X by 7 meant that successive values of the squares could be formed by addition. If a value X is equal to 7A, then the next value X is 7A+7.

X	N=X*X
7A	$49A^2$
7A+7	$49A^2 + 98A + 49$

So the difference between any two successive squares (values of N) will be 98A+49. Going a step further, the difference between two successive differences will always be 98. For example, here are the first four values of X and N, with the successive differences:

dX	X	N=X*X	M=dN	dM
--	3185	10144225	--	--
7 <	3192	10188864	> 44639	> 98
7 <	3199	10233601	> 44737	> 98
7 <	3206	10278436	> 44835	

So, I can write another program which looks a lot like the first one above but uses no multiplication to get the next value for N. Here it is:

```

100 N = 10144225:M = 44639:D = 98:L = 98988877
110 N = N + M:M = M + D
120 A = INT (N / 100000)
130 A1 = INT (A / 100):A3 = A - A1 * 100
140 A2 = INT (A3 / 10): IF A1 = A2 THEN 300
150 A3 = A3 - A2 * 10: IF A1 < > A3 THEN 300
160 B = ((A2 * 10 + A2) * 10 + A2) * 100
170 A = N - A * 100000
180 IF A < B OR A > B + 99 THEN 300
290 PRINT N
300 IF N < L THEN 110

```

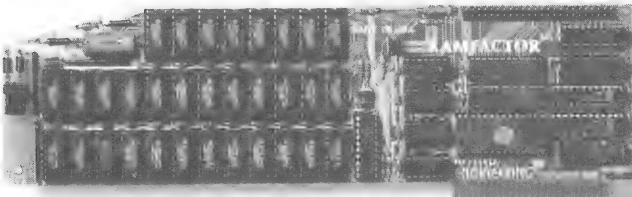
This version is slow again, taking about 52 seconds to run clear through. However, it will be the fastest one when running in assembly language. The assembly listing which follows implements the same algorithm, with a few minor differences. One key to its speed is that I keep the number N

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AppleWorks Power

There are other slot 1-7 cards that give AppleWorks a larger desktop, but that's the end of their story. But RamFactor is the only slot 1-7 card that increases AppleWorks internal memory limits, increasing the maximum number of records in the database and lines permitted in the word processor, and RamFactor is the only standard slot card that will automatically load all of AppleWorks into RAM dramatically increasing speed and eliminating the time required to access the program disk, it will even display the time and date on the AppleWorks screen with any ProDOS clock. RamFactor will automatically segment large files so they can be saved on 5 1/4", 3 1/2", and hard disks. All this performance is available on the Apple II+.

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in an 8-byte decimal format. This way I do not need to convert from binary to decimal for every value in order to test the individual digits against the pattern.

All of the arithmetic is done in on these unpacked decimal strings, with 8 digits per value. The variables N and M are initialized in lines 1050-1120, by copying in NN and MM. I did this so that I could execute the program enough times in succession to get a measureable time on my stopwatch. (Lines 1910-1960 execute the program ten times, and this took about 6 seconds.)

The additions to generate the next square and next M-value are done by lines 1140-1200, with the help of the ADD subroutine in lines 1640-1780. The subroutine assumes the Y-register contains the offset from STRINGS of the last (least-significant) digit of one of the addends, and the X-register contains the offset for the other addend. The result is stored in the string pointed to by the Y-register. Lines 1700-1720 are kind of neat: they limit each byte to the value of a single digit, and set up the carry for the next digit.

Lines 1210-1420 compare the value of N with the pattern ababbbcc. There are many possible ways to arrange the pattern tests, so I just picked one. The order of the tests affects the speed a little, but very little. The two tests in lines 1390-142 are "commented out" because they were not necessary. There are no additional values of N rejected because of those two tests. In other words, we could have said the pattern was abab..cc, where the two dots represent any digit which may or may not be the same as any of the other digits, and still we would only get one answer.

Lines 1430-1510 print any values of N which pass all the tests. Only one does, but it is fun to experiment with leaving out different tests (comment out various lines with BEQ or BNE opcodes between 1210 and 1420). Then you get more answers, because you are not being so picky.

Lines 1530-1580 test the value of N to see if it is still less than 99000000. We only have to test the first two digits to find this out. If they are both 9, then we are through.

	1000 *SAVE S.PUZZLE 9-87	
FDDED-	1010 *	
FD8E-	1020 MON.COUT :EQ \$FDED	
	1030 MON.CROUT :EQ \$FD8E	
	1040 *	
	1050 T	
0800- A0 07	1060 LDY #7	Copy initial values for
0802- B9 A4 08	1070 .0	NN, Y N and M
0805- 99 84 08	1080 STA N,Y	
0808- B9 AC 08	1090 LDA MM,Y	
080B- 99 8C 08	1100 STA M,Y	
080E- 88	1110 DEY	
080F- 10 F1	1120 BPL .0	
	1130 *---N = N + M-----	
0811- A0 0F	1140 .1	LDY #M-STRINGS+7
0813- A2 07	1150 LDX #N-STRINGS+7	
0815- 20 67 08	1160 JSR ADD	
	1170 *---M = M + 98-----	
0818- A0 17	1180 LDY #D-STRINGS+7	
081A- A2 0F	1190 LDX #M-STRINGS+7	
081C- 20 67 08	1200 JSR ADD	

081F-	AD	8A	08	1210	-----Check for ababbbcc-----
0822-	CD	8B	08	1220	LDA N+6 Get c
0825-	DO	31		1230	CMP N+7
0827-	CD	84	08	1240	BNE .3 ...notcc
082A-	FO	2C		1250	CMP N
082C-	CD	85	08	1260	BEQ .3 ...have c.....cc
082F-	FO	27		1270	CMP N+1
				1280	BEQ .3 ...have ac....cc
				1290	*
0831-	AD	84	08	1300	LDA N Get a
0834-	CD	85	08	1310	CMP N+1
0837-	FO	1F		1320	BEQ .3 ...have aa....cc
0839-	CD	86	08	1330	CMP N+2
083C-	DO	1A		1340	BNE .3 ...not aba....cc
				1350	*
083E-	AD	85	08	1360	LDA N+1 Get b
0841-	CD	87	08	1370	CMP N+3
0844-	DO	12		1380	BNE .3 ...not abab..cc
				1390	*** CMP N+4
				1400	*** BNE .3 ...not ababb.cc
				1410	*** CMP N+5
				1420	*** BNE .3 ...not ababbcc
				1430	-----Print the answer-----
0846-	A0	00		1440	LDY #0
0848-	B9	84	08	1450	.2 LDA N,Y Next digit
084B-	09	B0		1460	ORA #0" make it ASCII
084D-	20	ED	FD	1470	JSR MON.COUT
0850-	CB			1480	INY
0851-	CO	08		1490	CPY #8
0853-	90	F3		1500	BCC .2
0855-	20	8E	FD	1510	JSR MON.CROUT
				1520	-----IF N < 99000000 THEN LOOP----
0858-	AD	84	08	1530	.3 LDA N
085B-	C9	09		1540	CMP #9
085D-	90	B2		1550	BCC .1
085F-	AD	85	08	1560	LDA N+1
0862-	C9	09		1570	CMP #9
0864-	90	AB		1580	BCC .1
				1590	*
0866-	60			1600	-----RTS-----
				1610	*
				1620	* ADD S(Y) TO S(X)
				1630	*
				1640	ADD
0867-	A9	08		1650	LDA #8 DO 8 DIGITS
0869-	8D	B4	08	1660	STA DGT
086C-	18			1670	CLC START WITH CARRY CLEAR
086D-	BD	84	08	1680	.1 LDA STRINGS,X
0870-	79	84	08	1690	ADC STRINGS,Y
0873-	C9	0A		1700	CMP #10 NEED TO CARRY IF > 9
0875-	90	02		1710	BCC .2 ...NOT > 9
0877-	E9	0A		1720	SBC #10 ...MODULO 10, LEAVE CARRY SET
0879-	BD	84	08	1730	.2 STA STRINGS,X
087C-	88			1740	DEY NEXT DIGIT
087D-	CA			1750	DEX
087E-	CE	B4	08	1760	DEC DGT
0881-	DO	EA		1770	BNE .1 ...MORE, DO NEXT DIGIT
0883-	60			1780	RTS ...FINISHED
				1790	*
				1800	STRINGS
0884-	01	00	01		
0887-	04	04	02		
088A-	02	05		1810	N .HS 01.00.01.04.04.02.02.05
088C-	00	00	00		
088F-	04	04	06		
0892-	03	09		1820	M .HS 00.00.00.04.04.06.03.09
0894-	00	00	00		
0897-	00	00	00		
089A-	09	08		1830	D .HS 00.00.00.00.00.00.09.08
089C-	09	08	09		
089F-	08	02	06		
08A2-	00	01		1840	L .HS 09.08.09.08.02.06.00.01
				1850	*
08A4-	01	00	01		
08A7-	04	04	02		
08AA-	02	05		1860	NN .HS 01.00.01.04.04.02.02.05
08AC-	00	00	00		
08AF-	04	04	06		
08B2-	03	09		1870	MM .HS 00.00.00.04.04.06.03.09
					98,982,601
					10,144,225
					44,639

	1880	*		
08B4-	1890	DGT	.BS 1	
	1900	*		
08B5- A9 0A	1910	TT	LDA #10	DO "T" 10 TIMES FOR TIMING
08B7- 85 00	1920		STA 0	
08B9- 20 00 08	1930	.1	JSR T	
08BC- C6 00	1940		DEC 0	
08BE- D0 F9	1950		BNE .1	
08C0- 60	1960		RTS	
	1970	*		

Apple IIgs Firmware Reference

Apple says this book is "for hardware designers and programmers who want to work with the system firmware in lieu of using the Apple IIgs Toolbox routines to accomplish similar goals." I think that is far too narrow an audience. This is the book you need if you want to use the system monitor, the disassembler, and the mini-assembler. This is the book you need if you want to do any programming with the mouse, the serial ports, the interrupts, and more. And I cannot think of any IIgs owners who doesn't want at least some of that information!

This book does not include a commented assembly listing of the firmware. In the past Apple has published such listings, but they are evidently not planning to do so for the IIgs. It does include detailed programming information for all of the built-in I/O devices, via the "slot-based" firmware. No detail about the hardware for the serial ports or other I/O devices is included, just the firmware. I cannot imagine doing without this book. I think it will be the one I use the most, because it is the one that tells me about how I interact with my machine. Next to this will be the IIgs Hardware Reference, due from the publisher in a few weeks.

Addison-Wesley's price for this 327-page book is \$24.95, and it will be available at many bookstores. Or, you can order it from us for \$23, plus shipping.

Warning to Smart Port Programmers.....Tom Vier

This is a warning to those of you who may be writing code for the new IIgs Smart Port devices. I discovered what I think is a surprising and dangerous inconsistency between the Smart Port specification and the Apple SCSI Port.

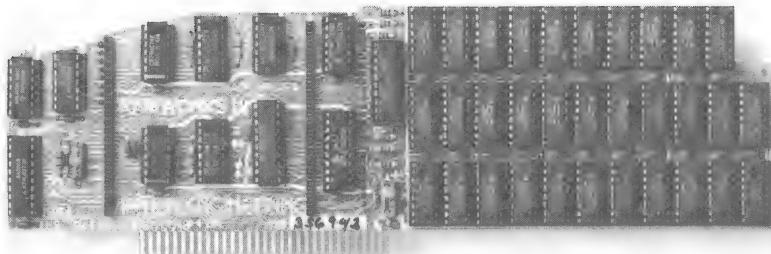
Recall that the Smart Port used to be called the Protocol Converter. On page 128 of the Apple //c Technical Reference Manual it shows that the Protocol Convert call with command \$04 and subcode \$04 will eject the disk from the Unidisk 3.5 drive. This fact has been published far and wide so that people can add code to their own programs to eject that little disk under program control.

Now along comes the SCSI port. One page 33 of the SCSI documentation it says that subcode \$04 under command \$04 does a FORMAT of the attached hard disk drive! This surprises me since the Smart Port specification has a separate command (\$03) for FORMAT.

So the warning is, do not blindly send out command \$04 with subcode \$04. Those subcodes are device-specific, so you have to first find out what kind of device is attached to the Port.

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While RamWorks III is recognized by all memory intensive programs, NO other expansion card comes close to offering the multitude of enhancements to AppleWorks that RamWorks III does. Naturally, you'd expect RamWorks III to expand the available desktop, after all Applied Engineering was a year ahead of everyone else *including Apple* in offering more than 55K, and we still provide the largest AppleWorks desktops available. But a larger desktop is just part of the story. Look at all the AppleWorks enhancements that even Apple's own card does not provide and *only* RamWorks III does. With a 256K or larger RamWorks III, *all* of AppleWorks (including printer routines) will automatically load itself into RAM dramatically increasing speed by eliminating the time required to access the program disk drive. Switch from word processing to spreadsheet to database at the speed of light with no wear on disk drives.

Only RamWorks eliminates Apple Works' internal memory limits, increasing the maximum number of records available from 1,350 to over 25,000. *Only* RamWorks increases the number of lines permitted in the word processing mode from 2,250 to over 15,000. And *only* RamWorks offers a built-in printer buffer, so you won't have to wait for your printer to stop before returning to AppleWorks. RamWorks even expands the clipboard. And auto segments large files so they can be saved on two or more disks. You can even have Pinpoint or MacroWorks and your favorite spelling checker in RAM for instant response.

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Applied Engineering has always offered the largest memory for the IIe and RamWorks III continues that tradition by expanding to 1 full MEG on the main card using standard RAMs, more than most will ever need (1 meg is about 500 pages of text)...but if you do ever need more than 1 MEG, RamWorks III has the widest selection of expander cards available. Additional 512K, 2 MEG, or 16 MEG cards just snap directly onto RamWorks III by plugging into the industry's only low profile (no slot 1 interference) fully decoded memory expansion connector. You can also choose non-volatile, power independent expanders allowing permanent storage for up to 20 years.

It Even Corrects Mistakes.

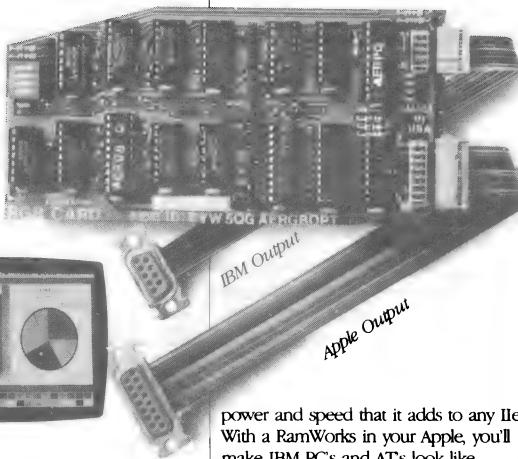
If you've got some other RAM card that's not being recognized by your programs and you want RamWorks III, you're in luck. Because all you have to do is plug the memory chips from your current card into the expansion sockets on RamWorks to recapture most of your investment!

The Ultimate in RGB Color.

RGB color is an option on RamWorks and with good reason. Some others combine RGB color output with their memory cards, but that's unfair for those who don't need RGB *and* for those that do. Because if you don't need RGB

Applied Engineering doesn't make you buy it, but if you want RGB output you're in for a nice surprise because the RamWorks RGB option offers better color graphics plus a more readable 80 column text (that blows away any composite color monitor). For only \$129 it can be added to RamWorks giving you a razor sharp, vivid brilliance that most claim is the best they have ever seen. You'll also appreciate the multiple text colors (others only have green) that come standard. But the RamWorks RGB option is more than just the ultimate in color output because unlike others, it's fully compatible with all the Apple standards for RGB output control, making it more compatible with off-the-shelf software. With its FCC certified design, you can use almost any RGB monitor because only the new RamWorks RGB option provides both Apple standard and IBM standard RGB outputs (cables included). The RGB option plugs into the back of RamWorks with no slot 1 interference.

RGB Option



ference and remember you can order the RGB option with your RamWorks or add it on at a later date.

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RamWorks III has a built-in 65C816 CPU port for direct connection to our optional 65C816 card. The only one capable of linearly addressing more than 1 meg of memory for power applications like running the Lotus 1-2-3™ compatible program, VIP Professional. Our 65C816 card does not use another slot but replaces the 65C02 yet maintains full 8 bit compatibility.

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A+ magazine said "Applied Engineering's RamWorks is a boon to those who must use large files with AppleWorks...I like the product so much that I am buying one for my own system." *inCider* magazine said "RamWorks is the most



*Steve Jobs, the creator
of Apple Computer*

*"I wanted a
memory card for
my Apple that was
fast, easy to use,
and very compat-
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powerful auxiliary slot memory card available for your IIe, and I rate it four stars...For my money, Applied Engineering's RamWorks is king of the hill."

Apple experts everywhere are impressed by RamWorks's expandability, versatility, ease of use, and the sheer

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- Accelerates AppleWorks
- Built-in AppleWorks printer buffer
- The only large RAM card that's 100% compatible with all IIe software
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- Memory is easily partitioned allowing many programs in memory at once
- Compatible, RGB option featuring ultra high resolution color graphics and multiple text colors, with cables for both Apple and IBM type monitors
- Built-in self diagnostics software
- Lowest power consumption (U.S. Patent #4601018)
- Takes only one slot (auxiliary) even when fully expanded
- Socketed and user upgradeable
- Software industry standard
- Advanced Computer Aided Design
- Used by Apple Computer, Steve Wozniak and virtually all software companies
- Displays date and time on the Apple Works screen with any PRO-DOS compatible clock
- Much, much more!

RamWorks III with 64K	\$179
RamWorks III with 256K	\$199
RamWorks III with 512K	\$249
RamWorks III with 1 MEG	\$329
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Apple IIgs ProDOS-16 Reference

Apple says this is "a manual for software developers, advanced programmers, and others who wish to understand the technical aspects of the Apple IIgs operating system." Here is a brief run-down of the contents:

- 1-5 -- About P16 (Files, Memory Management, External Devices, and the Operating Environment)
- 6 -- Programming with P16 (Revising a ProDOS-8 Application, and Using the Apple IIgs Programmer's Workshop)
- 7 -- Adding Routines to P16 (Interrupt Handlers)
- 8-13 -- Making P16 Calls (Complete description of all of the MLI calls supported by P16)
- 14-17 -- The System Loader (How to use the system loader to load and relocate programs, including a description of the 16 System Loader Calls.)

Appendix A -- P16 File Organization (Exactly the same as ProDOS-8, except that more file types are defined)

Appendix B -- Comparison of Apple II Operating Systems

Appendix C -- The ProDOS 16 Exerciser (Tells about the disk which comes with the book)

Appendix D -- System Loader Technical Data (Most of the information about the Object module format expected by the System Loader. More detail will be available someday in the "Apple IIgs Programmer's Workshop Reference".)

Appendix E -- Complete list of Error Codes for P16 and the System Loader

There is a good index, as well as a glossary. And to cap it off, a rather complete Reference Card. The card is printed with major headings in red ink, to make it easier to locate items in a hurry. It totals eight full-size pages, and includes all of the MLI calls, System Loader calls, and Error Codes. Most of the info you need to understand and build file description blocks is also included.

All of the important information is here. However, there are no programming examples. I suspect there were not any good ones available at the time the book was written. We still feel the need for a book like Gary Little's "Apple ProDOS Advanced Features" (which we cannot get anymore) which would lead us through step-by-step in writing ProDOS-16 programs. Gary's book was for the old ProDOS-8, but he or someone should bring out a ProDOS-16 book like it. We also wish Don Worth and Pieter Lechner would give us the equivalent to "Beneath Apple DOS" and "Beneath Apple ProDOS". This is probably asking too much, considering the size of the job.

The publisher's price for this 338-page book is \$29.95, and it will be available at most bookstores. Or, you can order it from us for \$27, plus shipping.

Another ProDOS-8 Bug in the IIgs.....Bob Sander-Cederlof

Back in December of 1986 we noticed that a target file written from the ProDOS S-C Macro Assembler when running on a IIgs contained garbage from locations \$9B through \$FF of every page of the file. We patched the Assembler at that time and made it work correctly, blaming the new version of ProDOS.

The problem seemed to be related to the fact that target file processing used a one-byte data buffer at location \$009A (yes, in page zero). Now, there is nothing in any ProDOS documentation warning against using a data buffer in page zero. Furthermore, ProDOS does not return any error code for such a buffer. I assume, and I still think I am correct, that the designers of ProDOS expected this to be legal. Nevertheless, it does not work correctly in the IIgs.

It turns out ProDOS was only indirectly at fault. Both the old and the new versions of ProDOS-8 show the same failure, but it is due to the 65816 processor rather than any changes to the ProDOS code.

The code at fault is the subroutine which transfers bytes of data from the caller's data buffer into the file buffer. This subroutine is at \$F326 in ProDOS 1.1.1; it is at \$F311 in versions 1.2, 1.3, and 1.4. The file buffer is the one specified when MLI was called to OPEN the file. (The one that always has to begin on a page boundary.)

This subroutine uses pointers at \$4E,4D and \$4C,4D to access the data buffer and file buffer, respectively. To simplify indexing, a trick is used. It is the trick that causes it to fail with pagezero data buffers in a IIgs.

A subroutine at \$F110 (in version 1.1.1) or \$F0F8 (later versions) sets up the two pointers. The pointer to the data buffer is modified to point some distance BEFORE the actual data buffer. The distance is equivalent to the low-order byte of the current file MARK. This way the same Y-register value can be used to index both the data and file buffers. Except in a IIgs, when the data buffer is in page zero.

For example, here are the data buffer pointer and Y-register values for three cases that might occur during a ".TF" write:

data buffer at \$009A file buffer at \$7C00			eff.addr	eff.addr
mark	\$4E,4F	Y-reg	non-IIgs	IIgs
\$xx99	\$0001	\$99	\$009A	\$00/009A
\$xx9A	\$0000	\$9A	\$009A	\$00/009A
\$xx9B	\$FFFF	\$9B	\$009A	\$01/009A

Notice that the last value on the last line has bank 1, rather than bank 0! For an explanation of how this happens, see the last paragraph on page 119 of "Programming the 65816" by Eyes & Lichty. Whenever an indexed instruction specifies a 16-bit

address and assumes the data bank as its bank, then, if the index plus the base exceeds \$FFFF the effective address will be in the next bank. (This allows data tables to straddle bank boundaries.)

What happens then, during a write? All bytes from \$xx00 through \$xx9A of each 256 bytes (in the case of my .TF processor) are written correctly. Bytes from \$xx9B through \$xxFF are taken instead from bank 1, location \$009A (the AUX bank). Whatever data exists there will be written on the file.

I wanted to test out my theories, so I wrote a quick and dirty little program to OPEN a file, WRITE 256 data bytes on it, and CLOSE it. I ran it using both versions 1.1.1 and 1.4 of ProDOS-8, and on both an Apple //e and a IIgs. Both versions of ProDOS worked correctly on the //e, and both failed on the IIgs.

My test program is so "quick and dirty" that you have to CREATE the file directly before running the program. If you want to try it, type "CREATE TESTFILE,TTXT" before running the program. Then to look at the data, type "BLOAD TESTFILE,A\$2000,TTXT" and use the monitor to print out the contents of \$2000-20FF. You may also need to change the pathname to that of your test disk.

By the way, the very same problem exists for READ calls using a data buffer in page zero. For example, using a one-byte buffer at \$009A would cause all bytes within the file which are at positions \$xx9B through \$xxFF to stored at \$01009A in a IIgs. Apparently nobody has tried this yet.

The current ProDOS version of the S-C Macro Assembler works correctly in the IIgs. There have been three changes to make this possible. First, we changed to the most recent release of the PRODOS file. Second, I moved my .TF buffer out of page zero. Third, I modified the "\$" monitor section to work with the new IIgs monitor. (This version still works in all older machines as well.) If you have recently acquired a IIgs and need an upgrade to your S-C Macro Assembler, let us know.

Don't you suppose that there are more programs out there besides ProDOS which could stumble over this difference in the way indexing works? And more besides our Assembler which will stumble over this quirk in ProDOS? Be wary.

```
1000 *SAVE S.TEST.WPZ
1010 *
1020 *----- TEST WRITING FROM A BUFFER IN PAGE ZERO
1030 *
9B- 1040 DATABUF .EQ $9B
FDDA- 1050 MLI .EQ $FDDA
      1060 PRBYTE .EQ $FDDA
      1070 *
      1080 T
0800- 20 00 BF 1090      JSR MLI      OPEN THE FILE
0803- C8 2A 08 1100      .DA #$C8,IOB.OPEN
0806- BO 1F 1110      BCS .99      ERROR
0808- AD 2F 08 1120      LDA O.REF    GET THE REFERENCE NUMBER
080B- 8D 31 08 1130      STA W.REF
      1140 *
080E- A9 00 1150      LDA #0      WRITE $00...$FF ON THE FILE
0810- 65 9B 1160      STA DATABUF
0812- 20 00 BF 1170 .1      JSR MLI
0815- CB 30 08 1180      .DA #$CB,IOB.WRITE
```

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```

0818- B0 0D    1190      BCS .99      ERROR
081A- E6 9B    1200      INC DATABUF
081C- D0 F4    1210      BNE .1
1220 -----
081E- 20 00 BF  1230      JSR MLI
0821- CC 38 08  1240      .DA #$CC,IOB CLOSE
0824- B0 01    1250      BCS .99      ERROR
0826- 60      1260      RTS
1270 -----
0827- 4C DA FD  1280      .99      JMP PRBYTE   PRINT THE ERROR CODE
1290 -----
1300 IOB.OPEN
082A- 03      1310      .DA #3
082B- 3A 08    1320      .DA PATHNAME
082D- 00 09    1330      .DA FILEBUF
082F-          1340      O.REF .BS 1
1350 -----
1360 IOB.WRITE
0830- 04      1370      .DA #4
0831-          1380      W.REF .BS 1
0832- 9B 00    1390      .DA DATABUF
0834- 01 00    1400      .DA 1
0836-          1410      ACTLEN .BS 2
1420 -----
1430 IOB.CLOSE
0838- 01      1440      .DA #1
0839- 00      1450      .DA #0
1460 -----
1470 PATHNAME
083A- 0E      1480      .DA #PSZ-1
083B- 2F 54 45
083E- 53 54 2F
0841- 54 45 53
0844- 54 46 49
0847- 4C 45
1490      .AS "/TEST/TESTFILE"
0F-          1500      PSZ .EQ #-PATHNAME
1510 -----
0849-          1520      .BS *+255/256*256-* FORCE PAGE BOUNDARY
0900-          1530      FILEBUF .BS 512 FOR FILE BUFFER
1540 -----

```

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EXEC and INPUT Bug in BASIC.SYSTEM.....Bob Sander-Cederlof

Michael Wertheim of Plantation, Florida wrote to Open Apple pointing out that Negative numbers can be read into an Applesoft program from the keyboard, or from an OPEN file, but not EXEC'd. Numbers that begin with a digit, a decimal point, or a plus sign work fine.

Open-Apple verified that Michael was correct. Under DOS 3.3 it works correctly, but under ProDOS you get a SYNTAX ERROR when you try to use EXEC to feed file-based data to an INPUT statement, and the line begins with a minus sign. They suggested using a string variable, and said that doing so made it work.

I tried that and found it did not work. Here is a listing of the program I used to test it out.

```
100 D$ = CHR$(4)
105 PRINT D$"CLOSE"
106 PRINT D$"OPEN TT"
107 PRINT D$"CLOSE"
108 PRINT D$"DELETETT"
110 PRINT D$"OPEN TT"
120 PRINT D$"WRITE TT"
130 PRINT 100: PRINT "-123": PRINT 145
140 PRINT D$"CLOSE"
200 PRINT D$"EXEC TT"
210 INPUT A
220 INPUT B
230 INPUT C
240 PRINT A,B,C
```

I tried various things, but none of them made it work. I thought maybe inserting an extra space before the minus sign would fix it, but it did not.

Then I thought, "Maybe BASIC.SYSTEM thinks the minus sign is a ProDOS '-filename' command."

I tested my idea by changing the variable B to B\$, and changing line 130 to

```
130 PRINT 100 : PRINT "-ABC" : PRINT 145
```

Sure enough, when I ran it with those changes instead of SYNTAX ERROR I got PATH NOT FOUND.

So, the bug is caused by the fact that BASIC.SYSTEM grabs and interprets the EXECed line before the Applesoft INPUT statement gets a chance.

Can you imagine the disasters this could cause? What if you were reading into a series of strings, and one of them happened to be "DELETE V.I.F." (where V.I.F. means Very Important File)?

The moral of the story is, DO NOT use EXEC to get data for INPUT statements. Use OPEN and READ, get your INPUT, and then use CLOSE.

New Advice

Open-Apple's Tom Marshall's monthly newsletter for knowledgeable Apple II users. It's thin but packed tight with Apple II lore, humor, letters, tips, advice, and solutions to your problems. Compared to other Apple II publications, Open-Apple has the highest new-idea per issue ratio, the clearest writing, the funniest cartoons, the longest index, the only warranty (all your money back if you're not satisfied), and it takes up the least shelf space. The only thing it doesn't have is the most subscribers. Yet.

II cue #13

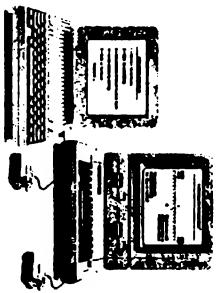
When you specify information about your printer, AppleWorks asks whether your printer supports top-of-page (form feed) commands. Almost all printers do. However, you'll find that with many printers, including the ImageWriter, the page length function within AppleWorks will not work correctly unless you specify "no" for "accepts top-of-page commands." For much more about dealing with

printers, see our November 1985 Special Issue: Solving Printer Problems.

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Signed and Unsigned Comparisons.....Bob Sander-Cederlof

Judging from a lot of the programs I read in magazine or purchase and then disassemble, there are a lot of people who have not learned the EASY ways to compare two values in the 6502.

One reason may be that other microprocessors do things differently. Perhaps a programmer adept in Z-80 had to quickly learn the 6502 for a particular programming assignment.

Another factor may be the confusing write-ups in various manuals and magazine articles of the past. One in particular I re-read yesterday was specifically written to clear up the confusion, but someone changed one letter in every listing, changing a BVS opcode to BVC, thereby destroying every example. I hope that I do not add any confusion today!

There is also confusion caused by the very design of the 6502. There is no opcode in the 6502 for "branch if less than", or "branch if greater than or equal". If the CMP or SBC opcode is used to do the comparison, and if the values being compared are considered to be unsigned magnitudes, the BCC and BCS opcodes can fulfill these functions. Consequently many 6502 assemblers include BLT and BGE mnemonics which are simply aliases for BCC and BCS.

The previous paragraphs mentioned "unsigned magnitudes". Memory locations simply hold 8-bits of data. An individual byte may be considered to be an ASCII character, a two digit decimal number, a binary number with no sign of magnitude between 0 and 255, a signed binary number between -128 and +127, or anything else the programmer desires. Obviously it makes a difference. You cannot use the same methods to compare unsigned magnitudes, for example, as you would to compare signed values.

Equality Comparisons

Let's start with the simplest case. Suppose you have two single-byte values and you want to compare them to see if they are equal or not. Believe it or not, even this is not cut-and-dried. One of the values is in a variable called LEFT, and the other in RIGHT. Here is one way to do the test:

```
LDA LEFT
CMP RIGHT
BEQ L.EQ.R
...           here if LEFT not equal RIGHT
```

The comparison is done in this method in the A-register. I could just as well have used LDX and CPX to do the comparison in the X- register, or LDY with CPY to do it in the Y-register. I could also make the third line BNE L.NE.R, and let the code fall through to the L.EQ.R code.

You can also use the SBC opcode to compare for equality, although it is not as efficient since you have to start by setting Carry:

```
SEC  
LDA LEFT  
SBC RIGHT  
BEQ L.EQ.R
```

Using SBC, CMP, CPX, or CPY to compare two bytes may have an undesirable side effect in your code. These opcodes also may change the Carry status bit. If you have important information in C, you may want to use a different method. The EOR (exclusive-or) opcode will generate a zero value if and only if the two operands are equal. Therefore you can use:

```
LDA LEFT  
EOR RIGHT  
BEQ L.EQ.R
```

This reminds me of a common error in 6502 code. Some microprocessor do not set the EQ/NE status unless you use a specific comparison opcode. The 6502 does it after any opcode which puts a value in a register. Over and over I have seen code like this:

```
SEC  
LDA LEFT  
SBC RIGHT  
CMP #0  
BEQ L.EQ.R
```

That CMP #0 is totally wasted. (Another waste I have frequently seen is setting or clearing Carry before a CMP opcode. You need it before ADC and SBC, but it is useless before CMP.)

What if LEFT and RIGHT are 16-bit variables? Then you can do it this way:

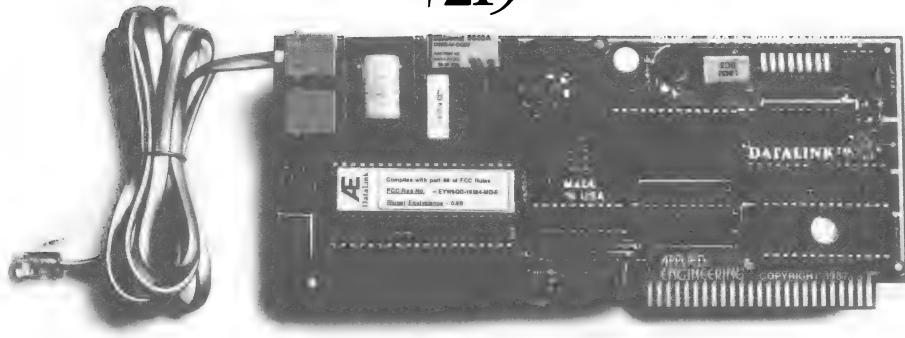
```
LDA LEFT  
EOR RIGHT  
BNE L.NE.R  
LDA LEFT+1  
EOR RIGHT+1  
BNE L.NE.R
```

What if LEFT and RIGHT are 8-bit variables, but I only want to check certain bits for equality with the bytes, not all bits? I have another variable, MASK, which has 1-bits in those positions which I want to check:

```
LDA LEFT  
EOR RIGHT  
AND MASK  
BEQ L.EQ.R
```

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Greater Than and Less Than

In order to compare two variables and determine which one is larger in value, we have to know something about the MEANING of the values. For example, if the values are ASCII characters, we may want "A" to be considered less than "Z" for purposes of an alphabetic sort. Nevertheless, we also want "A" to be EQUAL to "a"! Even if the values are binary numbers there are still several possibilities.

The following chart shows some popular numbering schemes:

Scheme	Smallest to Largest	Range
unsigned magnitude	00...7F 80...FF	0...255
2's complement	80...FF 00...7F	-128...+127
1's complement	80...FE (FF,00) 01...7F	-127...+127
sign/magnitude	FF...81 (80,00) 01...7F	-127...+127

The first two are the ones usually used in the 6502 world. In 1's complement and sign/magnitude there are two values for zero, called +0 and -0. These schemes are built into the hardware in some machines, believe it or not. I used to like 1's complement in the Control Data Corporation computers, and I liked sign/magnitude in the venerable Bendix G-15. You may occasionally find uses for these in the 6502, but normally you will be using unsigned magnitude or 2's complement.

Notice that when comparing two values which are unsigned magnitudes, \$FF is the largest value. When comparing two values which are in 2's complement, \$FF is smaller than \$00, and \$7F is the largest value! Obviously we have to use different code for these two comparisons.

The 6502 add, subtract, and comparison opcodes work equally well on magnitudes or 2's complement values. You just have to know how to interpret the results. When working with magnitudes we need to keep track of the Carry status; when working with 2's complement we need to keep track of the Sign and the Overflow status.

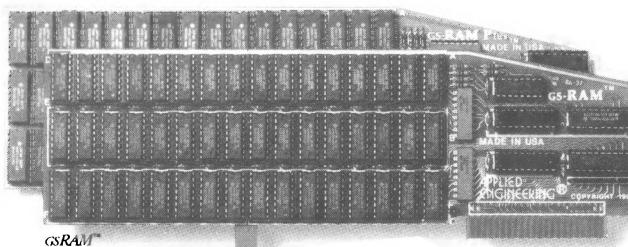
Here are some coding segments for comparing single byte variables in both magnitude and 2's complement forms. The code branches to L.GE.R if LEFT is greater than or equal to RIGHT, and falls through if LEFT is less than RIGHT:

magnitude	2's complement
	SEC
LDA LEFT	LDA LEFT
CMP RIGHT	SBC RIGHT
BCS L.GE.R	BVC .1
	EOR #\$FF
.1	BPL L.GE.R

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With an optional piggyback card, you can expand gsRAM even higher than 1.5 MEG! (Other cards are only expandable to 1 MEG.)

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gsRAM with 2-8 MEG	CALL
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The following code branches to L.LE.R if LEFT is less than or equal to RIGHT, and falls through if LEFT is greater than RIGHT:

magnitude	2's complement
	SEC
LDA RIGHT	LDA RIGHT
CMP LEFT	SBC LEFT
BCS L.LE.R	BVC .1
	EOR #\$FF
.1	BPL L.LE.R

The following code branches to L.EQ.R if LEFT is equal to RIGHT, to L.GT.R if LEFT is greater than or equal to RIGHT, and falls through if LEFT is less than RIGHT:

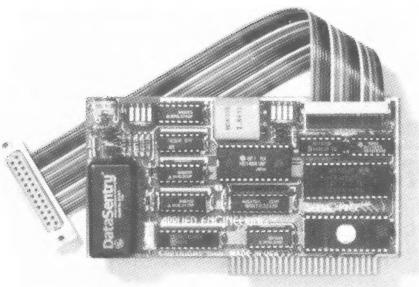
magnitude	2's complement
	SEC
LDA LEFT	LDA LEFT
CMP RIGHT	SBC RIGHT
BEQ L.EQ.R	BEQ L.EQ.R
BCS L.GT.R	BVC .1
	EOR #\$FF
.1	BPL L.GT.R

Now here are some coding segments for comparing double byte variables in both magnitude and 2's complement forms. These examples perform the same as those given above, but consider 16-bits rather than 8:

magnitude	2's complement
	LDA LEFT
LDA LEFT	LDA LEFT
CMP RIGHT	CMP RIGHT
LDA LEFT+1	LDA LEFT+1
SBC RIGHT+1	SBC RIGHT+1
BCS L.GE.R	BVC .1
	EOR #\$FF
.1	BPL L.GE.R

Notice that the low-order bytes are compared in both cases as magnitudes, which they are. If LEFT is greater than or equal to RIGHT, Carry will be set; otherwise, it will be cleared. This primes the pump for the SBC of the high-order bytes. You can extend this to any larger number of bytes by just including more LDA-SBC pairs (after the one shown) for all the higher-order bytes in sequence.

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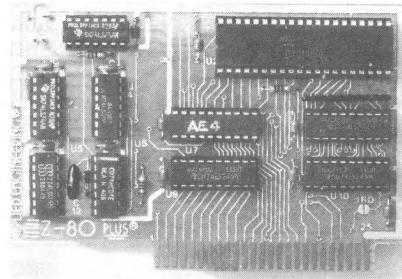
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Here is the pair of code segments for the "less than or equal" comparison:

magnitude	2's complement
LDA RIGHT	LDA RIGHT
CMP LEFT	SBC LEFT
LDA LEFT+1	LDA LEFT+1
SBC RIGHT+1	SBC RIGHT+1
BCS L.LE.R	BVC .1
	EOR #\$FF
.1	BPL L.LE.R

Here is the pair of code segments for branching three ways:

magnitude	2's complement
	SEC
LDA LEFT+1	LDA LEFT+1
CMP RIGHT+1	SBC RIGHT+1
BNE .1	BEQ .2
LDA LEFT	BVC .1
CMP RIGHT	EOR #\$FF
BEQ L.EQ.R	.1 BPL L.GT.R
.1 BCS L.GT.R	BMI L.LT.R
	.2 LDA LEFT
	CMP RIGHT
	BEQ L.EQ.R
	BCS L.GT.R

This one was a lot trickier, because of the need to separate the EQUAL case. I reversed the order of the tests, testing the high-order bytes first.

There are many other variations and many other ways of doing the same thing. I hope this helped to shed some light, and will help you to write more efficient and more clear code in the future.

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